**Making the Best Decisions: Traffic Regulation on a Simulated Section of Highway**

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**Abstract**

Traffic during peak hours can range anywhere from slightly frustrating to a major problem. There are many reasons why traffic can get backed up. More obvious reasons would be wrecks or broken down vehicles. Other more common and more preventable reasons are direct results of the people driving the cars. It is very possible that with new driver education initiatives, we could reduce the impact of these mistakes, but with self-driving cars in development, it is not a big step further to envision a network of self-driving cars regulated by one decision-making intelligence. This project will seek to model a small piece of highway and use a decision-making controller to increase efficiency in travel, a reduction in congestion, and show that it is reasonable to conclude safety could be greatly improved by such a system in the real world. Any conclusions drawn from the project will admittedly be purely theoretical given our simplistic model, but we will strive to show that our model is a good abstraction of the real world that takes into account the most important details of the state and environment.

**Introduction**

Traffic research is a relatively young area of science. Much thought is put into the construction of roads and highways and the existing systems that regulate flow: stop lights at intersections, stop lights that limit the flow of cars at an on ramp to a freeway, etc. Safety and flow of traffic have been greatly improved with these measures, but ultimately they cannot be anywhere near foolproof; because the fools the safety measures are protecting are very good at making mistakes. A well thought-out decision-making machine that manipulates each car on the road could, within reason, and barring inevitable mechanical and other failures, create a zone of accident free traffic that flows at close to maximum efficiency given the volume of cars on the road at any time.

**Background**

A stretch of highway observed from an artificial intelligence point-of-view is an environment full of agents. These agents are obviously humans, the very things that artificial intelligence strives to emulate. But taking into consideration the average human’s skill in driving and the fact that each person has only limited knowledge of what is happening in the system outside of a very limited scope, a person driving a car could be reduced down to a more basic form: a simple agent in a dynamic environment that acts on a few parameters (a goal destination and sensory input, mostly). These agents work next to each other in an ever-changing environment, making decisions based on the agents in the surrounding area. Most people are reasonably polite on the road, so each agent is not necessarily always taking the action that leads directly to a state closer to their individual goal. However, the fact remains that drivers have very limited knowledge of the other drivers’ goals. Besides allowing another driver to merge when his or her blinker is on, there are not many ways for drivers to work together. This is not a system that lends itself to efficiency, especially when you mix in human error.

Human error is the greatest cause of traffic congestion and is the reason that most drivers never get even close to operating their cars at the highest efficiency possible in any situation. Wrecks are obviously a cause of congestion and traffic jams. Given that wrecks are more likely to occur during times of heavy volume, the effects of an accident are multiplied across and along many lanes of traffic, even on the other side of the highway, via rubbernecking. One of our system’s goals is to prevent any wrecks that involve human error from ever occurring.

Oftentimes, one is driving down a highway, only to find that traffic is slowed almost to a standstill, with brake lights flashing on and off as far as the eye can see. After spending ten minutes in traffic, suddenly ahead there is… nothing but free flowing traffic. The phenomenon that was experienced is the lasting effects of a congestion-causing incident (like an accident). There wasn’t anything blocking the road, but the “wave” of traffic that had stopped for the wreck multiplied in length; even after a wreck is removed, there will still be cars slowing at the end of the line. Only when the line of condensed cars that stopped or slowed for the accident has dispersed will traffic flow return to normal speeds. The rate at which cars exit this wave must be greater than the rate at which new cars join the wave. This effect is somewhat akin to the way a worm moves. The condensed part of the worm moves down the length of its body in the same way that condensed traffic moves down the length of the highway. These observations are not to say that simply by eliminating accidents will these traveling waves of slowed traffic no longer be an issue. It does not take an accident or broken-down vehicle to cause a wave that has long-lasting and detrimental effects. It could simply be a car momentarily hitting the brakes. In fact, an experiment done at the University of Nagoya in Japan has shown that these compounding jams can occur even with people driving in a circle at reasonable speeds with a reasonable volume of cars (see: Shockwave Traffic Jams below). The jam shown in the video of this experiment is surprising. Even in a closed system with no need to stop, congestion seems to appear from nowhere.

Merging is one other extremely common cause of waves of traffic. All it takes is one car to enter the highway below the common speed, or one car to cut off another, to birth a wave of traffic that will result in brake lights and slower speeds that can multiply and increase for miles. Our system will focus heavily on ensuring that lane changes are made safely and in a way that only slows down other cars if completely necessary.

Congestion avoidance is not the only goal of our project. There will be a point of volume when congestion is bound to happen, no matter how efficiently traffic is organized. In cities where traffic volume is famously heavy, a traffic regulation system would only help so much; when a highway is completely filled with cars, the principles that guide the construction of our system will not have much effect. Another main focus of the project will be efficiency. Cars are most efficient at steady speeds, and the advantage of being able to monitor all the cars on a road at once cannot be understated when talking about fuel efficiency. If any number of slowdowns can be avoided on a road, a small amount of fuel can be saved. Multiplied over many cars over time, it could be significant.

The idea of a traffic system controlling all of the cars on the road also brings into play some new ideas. One such concept has to do with following distance while driving. It is recommended to leave several seconds of space behind the car in front, for safety. It is never certain when the car in front may brake hard, so it is best to leave a cushion. Similarly, at a stop light where a long line of cars has accumulated, the cars at the end of the line begin moving much later than the cars at the front, because everyone lets a little space open in front of their cars. This is a necessary evil in an environment where humans are controlling their vehicles with very little knowledge of the intentions of others, but may no longer be necessary with a traffic system. Think about the way train cars move. Except for a small amount of play in the linkages between the cars, they all move as one. When the car in front moves, the car behind moves too, almost at the same time. There is not condensing at stops, and no lengthening once the train begins to move again. This is ok because the cars always move at the same time and when one of them stops, they all will stop. There isn’t a time when one car will stop too fast without any warning. They essentially move as one. Obviously, we don’t want cars to move exactly as a train does. They cannot be hitting each other constantly. But when the cars are all controlled by a system that knows where they are at all times, knows how fast they are all going, and can tell multiple cars to stop simultaneously, there is no reason that, barring mechanical failures, a line of cars couldn’t be almost bumper to bumper moving at speed. This could be applied at stop lights, but our project will demonstrate their use in a situation after a wrecked car has been removed from the highway. The line of cars that accumulated behind the wreck will have stopped, but once the wreck was removed, they will be able to get moving again much faster, reducing the amount that the size of the traffic wave increases. Practically, there are a million factors to keep track of in this situation given the complexity of the real world. Different cars have different braking factors. Heavier vehicles like large trucks require a larger space for stopping. There are different types and qualities of brake, and brakes wear out and become less effective over time. Our model will admittedly ignore these concerns for simplicity. The cars in the simulation will be exactly the same as far as mechanical ability. To attempt to mimic the myriad aspects of even this small part would take too much time so we will attempt to show that the underlying theory is sound to a point.

Our focus is to create a simulation that will learn how to control traffic to increase efficiency, speed up recovery from congestion after a wreck, and hopefully reduce travel times. A real world implementation of this controller would have to learn and react in real time. The system would have to keep track of many statistics about the current state of the road: number of cars and congestion level, speeds and average speeds, the amount of speeding up and slowing down that is happening. All of these stats would contribute to the decision the system makes in giving each car instructions on how to act to achieve the goal of maximum possible efficiency in traffic flow.

**Setting Up**

We are doing this project using a JavaScript game engine “simpleGame.js” (see “simple game” below). To create the structure for the simulation we decided to create three objects.

The first object simply represents a car. It doesn’t have much to it since another object will be controlling the cars directly. There are functions for acceleration, deceleration, and emergency stopping that just change the speed of the car according to whatever directions given by the system. There is a function that reports the estimated mpg the car is getting at the current frame, based solely on the current speed. Using a chart for a typical car’s mpg, we found the curve for that graph and applied that to an estimated speed in miles per hour that is converted from the speed number in the game engine (in pixels per frame, 20 frames per second). We may collect other statistics, such as amount of time spent speeding up or braking, as those could also be benchmarks for learning and indicating that efficiency has been increased.

The next object is the controller. It will direct all the cars according to one main parameter: a calculated recommended speed for the highway. This speed is basically what the average speed of the cars are traveling. Since part of our goal is to reduce condensed traffic that causes traffic waves and to increase efficiency, we will try to reduce the amount of time spent speeding up and slowing down. We will try to accomplish this by using the average speed, which includes the times the cars are stopped and the times they speed up only to stop again. By having cars travel at this average speed, it should help prevent cars from bunching up and creating jams, and also, with any luck, reduces travel times. Having cars travel at this speed may not necessarily result in a drastic drop in travel time, but it is easy to see that engine and brake wear will be reduced, and mpg will increase. In addition to the focus on efficiency, the controller should ensure safety on the road. Our original intention was to have the controller handle each car’s desire to change lanes, and execute the lane change safely, but we have decided to hold that off in favor of the aforementioned goal.

The last object will be handling the creation of the simulations. We have normalized a data structure that holds the information on when cars are supposed to enter the road and in what lane. They are then passed to the controller to be given the speed at which the controller has decided cars should go.

**The Simulations**

This project will be demonstrated in three simulations. The first is to be simply an example of congestion. Many cars on the road at once, traveling at various speeds, will cause some drivers to brake. At first we will allow the cars to drive at whatever speed they want, resulting in congestion and traffic waves. After that, we will demonstrate the learning aspect of the controller. The controller will collect stats on the cars and calculate and continuously improve a good speed for the cars to drive at. If we accomplish this with enough time left, we may have the controller store information learned in this simulation and continue to train it until it can respond to any number of levels of traffic volume appropriately.

The second simulation will represent a situation where a wreck occurs and is removed after a time. First off, the cars will move independently of each other, resulting in a long line of stopped cars that moves in a wave. Then we will demonstrate how the controller can handle the situation. All cars entering the road behind the wreck should be slowed down before reaching the wreck to reduce the amount of cars that accumulate at the end of the line of stopped cars. The controller will then move the stopped cars all together to reduce the amount of time it takes for traffic to return to normal flow.

The third simulation is similar to the second. It will be a deer jumping out onto the road, resulting in an emergency braking situation. The controller will be making sure all cars stop at the same time, slow cars entering the road behind this line of stopped cars, and move all the cars as one to get traffic to flow again as soon as possible.

The purpose of these simulations is to demonstrate the value of a system to control traffic using self-driving cars connected together. We want to ensure that we show how such a system could learn, in real time, how to regulate the speed of traffic to result in our goals being met.

**Determining the “Best” Speed of the Road**

In discussions about how to accomplish a learning algorithm for finding the “best” speed for the road in our simulations, several strategies were brought up. Our course of action was decided with visual results in mind. We want to be able to have a system that takes several inputs (statistics about the road itself) and weigh those accordingly to come up with this best fit speed. A more complete way to go about this would be to totally generalize the way our project learns so that it could be applied to any test data and perform to a high standard. In reality though, the training for such a system would take a very long time, and implementing the system in order to teach it has complexities we don’t think we could abstract and complete in time. So we have decided on giving our controller these 3 situations to respond to, and focus on equipping it to fine-tune its ability to regulate traffic within the simulations. We hope to give the controller the ability to be an expert on handling these limited situations.